Real-Time Monitoring and Control of Solar-Powered Aquaponics System Using LabVIEW

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Abstract- *India is one of the country, hugely depends on agriculture. Above 67% of the population is working as farmers and in lower grades, like labor. But the farmers have almost 80% of holidays which is not productive. Due to rapid industrialization and concretization most of the lands are no more arable and it is continuously decreasing. Aquaponics is the solution for situations like this in a country where population density is 382 persons per sq.km. In this project we are providing one of the optimum solution to this drawback, we followed sensors based approach, using which, we can provide continuous monitoring and control of aquaponics system. In this way a farmer can yield 365 days an year. The solar powered smart monitoring system is a semi-autonomous system, where it requires least human involvement. We have used real time monitoring of both aquaculture and hydroponics using multiple sensors. Provision for real-time actuating system for necessary control operations are also been proposed in this system. The system prototype has been designed.*

Keywords- LabVIEW, Hydroponics, Fish Culture, Aquaponics, Arduino, LIFA (LabVIEW Interface for Arduino).

I. INTRODUCTION

Aquaponics is a farming method, a combination of hydroponics and conventional aquaculture in a symbiotic environment. Hydroponics is a technique of growing plants, soil-less and aquaculture is raising of fish in aquaculture tanks. The aquaculture tank contains ammonia rich fish effluent, these nutrients contaminate fish water and increases toxic levels in fish tank. In our system we pump this water from fish tank to hydroponic beds. Ammonia (NH_3) is an important source of nitrogen for plants, and are converted into organic fertilizers by the living bacteria, such as rhizobacteria in the hydroponic beds. The water is filtered by the plant roots which can be again used for the fish habitation. In this way an aquaponics system allows both fish and plants to grow together. In this way an aquaponics system serves a sustainable food production model which has several advantages such as, reuse of water, local food production, which enhances local economy etc. This project goal is to design an autonomous system which controls the parameters like air temperature, water temperature, relative humidity, light, and pH, turbidity and water level.

II. SYSTEM ARCHITECTURE

Water Recirculation System

One simple system for water recirculation is a CHOP system that stands for Constant Height One Pump system. In this system, it has a sump tank, aquaculture tank for fish and hydroponic bed for plants. A submersible water pump is used in this system to deliver water to fish tank continuously from the sump tank. The fish tank has constant head through which the water is fed to the hydroponic beds. This water is filtered in the hydroponic beds and drained to the sump tank again at regular intervals. With the help of CHOP system, the water level in the fish tank is constantly monitored and maintained to deliver an effective system to use. This is done to get rid of the stress being felt by fish during water fluctuations. Since only one pump used, power saving is an added advantage.

The CHOP system design is as shown in Figure 1. Optimal water flow rate decides the size of fish tank and the water flow rate. In general water circulation is done twice in an hour. Hence for a system of 100 liters volume of water requires the flow rate to be 200 liters per hour. Grow bed size is determined as 1:1 ratio of grow bed volume to fish tank volume.

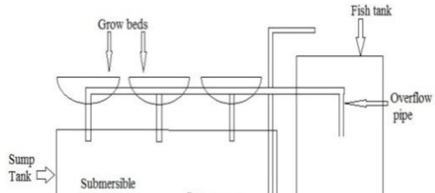

Figure 1: Water Recirculation system (CHOP)

Block Diagram of Aquaponics System

The aquaponics monitoring and control system can be represented as shown in figure 2. In reference to the block diagram, Arduino microcontroller reads the data from all the sensors via the signal conditioning circuits and process the data, these factors decide the water quality parameters of the hydroponic beds and the aquaculture tank, also the environmental parameters of the greenhouse. The Arduino microcontroller checks the read values and parameters to the reference values and activates the actuators through microcontroller to perform controlled operations. The actuators used here in the project are water pump, artificial lights, exhaust fan, aeration pump and cooler. These parameters are triggered by microcontroller through the driver circuits in case of parameters are not within the normal sweep.

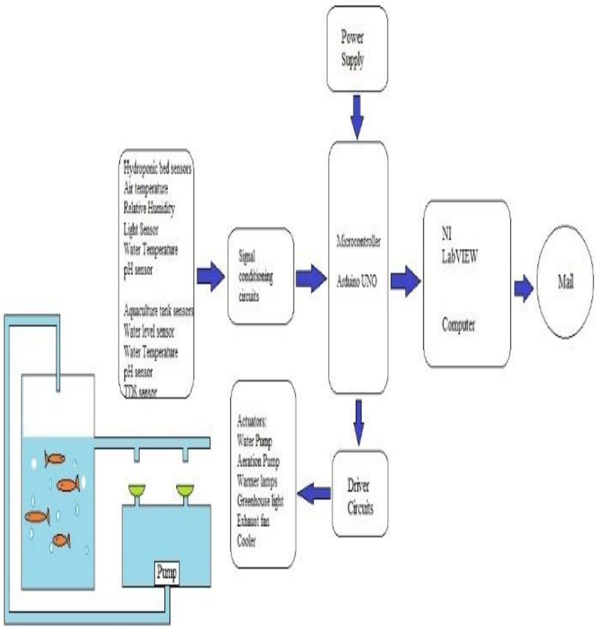

Figure 2: Block Diagram of Aquaponics control and Monitoring System

The gathered real-time data by Arduino microcontroller are displayed in GUI of NI LabVIEW software for monitoring purposes. The data acquisition are periodic whose period can be varied, to store the data logs, data are exported from NI LabVIEW to MS EXCEL sheet for system tracing. SNTP server configuration has been used to send alert mails to the authorized personnel, which contains critical parameters.

Monitoring and Control of Environmental Parameters

We are monitoring few environmental parameters in this project, they are air temperature, light intensity and relative humidity inside the greenhouse. These parameters are monitored and controlled automatically to enhance the photosynthesis rate and also plant growth in the hydroponic beds. The threshold values are set based on the citations [8]-[10] for the optimum growth plants in hydroponics bed. Critical parameters are monitored and controlled through actuators to maintain feasible conditions for plants.

Monitoring and Control of Water Quality Parameters

The water quality parameters monitored and controlled in this project are pH level, water temperature, total suspended solids and electrical conductivity for maintaining the desirable growth of plants in the hydroponic beds and to maintain optimum conditions for fish growth in aquaculture tank.

pH level is the measure of alkalinity and acidity of water in aquaculture tanks and hydroponic beds. The feasible range of pH levels for most plants is 5.5 to 7.5, if this range is violated, plants will experience nutrient deficiencies. Also fish in aquaculture tank grow best in the pH range of 6.0 to 9.0 [8] and can tolerate pH range of 5.5 to 10 [9]. LM35 is used for measuring the temperature of water in 0C inside the aquaculture tank. The normal range of water temperature is 160C to 330C. To measure the water level, an ultrasonic sensor is used at the top of fresh water supply tank in centimeters. Total suspended solids / Turbidity is the dry weight of suspended particles that are not dissolved which in turn pollute the water. 1 to 50 mg/L is published range and. Reduction of 67% to 83% is significantly influenced by water flow rates. The electrical conductivity (EC) is the measure of how well the water in aquaculture tank conducts electricity and this can be correlated to its salt content [9]. EC specifies the total ionic content of water, this will also indicate the freshness of water.

Heating and Cooling System of Greenhouse

Evaporative cooler of a pad and fan type is used to cool the air inside the greenhouse through evaporation of water. This method can drop temperature of dry air significantly through phase transition of liquid water to evaporation, this can cool air using much less energy than refrigeration [10]. The heating requirement of greenhouse depends on the desired temperature for plants being grown. Most of the heat requirement for greenhouse come from sun. Whereas, a heat source is provided to warm greenhouse to a temperature more than few degrees in reference to outside temperature. The heating system should be sufficient to maintain the required day and night temperature. We have used a warmer lamp as heating source for greenhouses and aquaculture tank usually during winter time.

Solar Energy Conversion System

We have used 12W, 21.6V PV panel, and one 12V – 9Ah rechargeable battery are utilized which are designed to discharge at 50% for prolonged battery life. A PWM solar charge controller with 10A, 12/24V rating is considered. Switched mode power supplies provide regulated 12V and 5V DC voltages to the electronic sensors and circuits. Block diagram can be as shown in Figure 3 below.

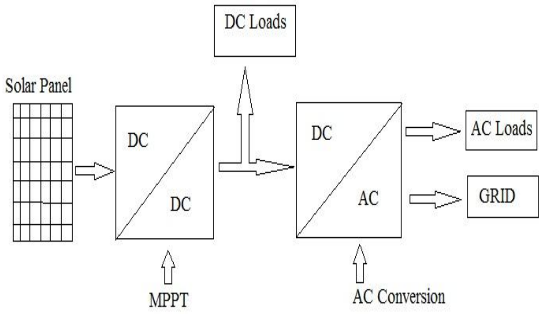

Figure 3: Block Diagram of solar energy conversion system

III. HARDWARE IMPLEMENTATION

In hardware implementation, sensing of water level, humidity, air temperature, light intensity, pH, turbidity and water temperature is involved. An Arduino microcontroller is used in the system for control and monitoring of data.

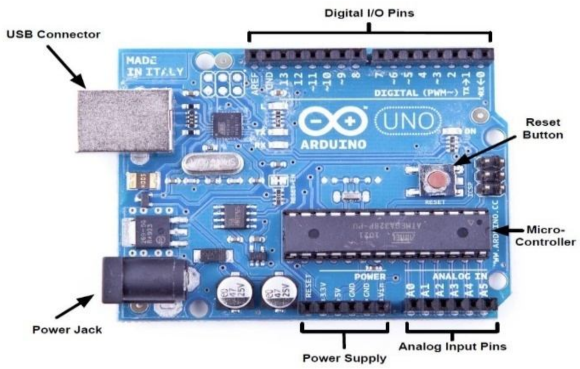

Figure 4: Arduino UNO

Ultrasonic Sensor

Ultrasonic sensor here is used to measure the water level in the aquaculture tank. It employs the method of measuring distance to object using sound waves. The working is by sending out an ultrasonic wave and waits for it to comeback from the object. The time delay between sent and received signal is used to calculate the distance.
Formula: Distance = (Speed of sound*Time delay)/2.

Figure 5: Ultrasonic sensor HC – SR04

DHT11

DHT11 is a temperature and humidity sensor that we have used to find the air temperature and relative humidity of the greenhouse in our project. DHT11 is an analog sensor where there is no need of serial communication and the data acquisition from the sensor to the Arduino. This sensor gives the real-time value with most accuracy.

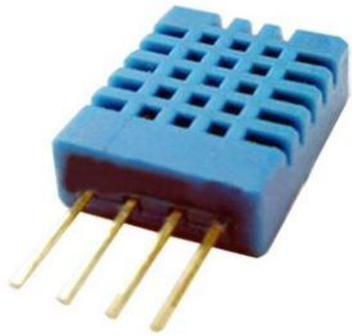

Figure 6: DHT11 Sensor

LDR

LDR is a light sensitive resistor whose resistance is inversely proportional to intensity of light it is exposed to. They are often used to indicate absence or presence of light or to measure the light intensity. The resistance is very high in dark up to 1MΩ, but when they are exposed to light resistance drops in huge amount. LDR is depicted as shown in figure 7.

Figure 7: LDR/Photo resistor

pH Sensor with Probe

pH is a measure of alkalinity or acidity of a solution, the pH scale ranges from 0 to 14. pH value indicates the concentration of hydrogen (H+) ions in the solution. Calculation of pH using electrode is the quantitative measurement of potential difference between two electrodes: a reference electrode (silver chloride or silver) and a hydrogen ion sensitive glass electrode. An electronic circuit is used to condition the signal appropriately so that it can be used with a microcontroller such as Arduino.

Figure 8: Glass electrode pH sensor

Figure 9: Signal conditioning circuit

Turbidity Sensor

Turbidity sensor is used to detect water quality, it measures levels of turbidity. With the use of light to detect suspended particles in water by measuring transmittance of light and scattering rate as these changes with the total suspended solids (TSS). As TSS in water increases, the turbidity level increases. The turbidity module is as shown in figure 10 below

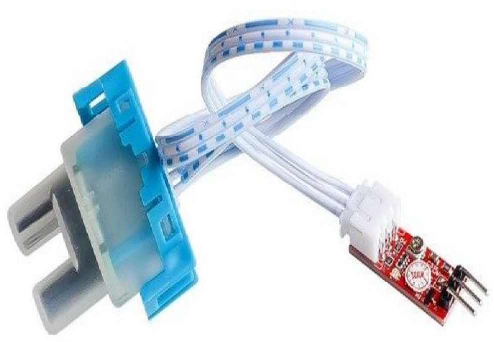

Figure 10: Turbidity measuring module

LM35 as Water temperature Sensor

LM35 series are precision integrated-circuit temperature devices which produces output voltage linearly proportional to temperature in centigrade. LM35 doesn’t require any external calibration for accuracy. Sensor operates over a -550C to 1500C temperature range. LM35 is used as a water temperature sensor by enclosing the IC into a water-proof shield as shown in figure 11

Figure 11: Temperature Probe

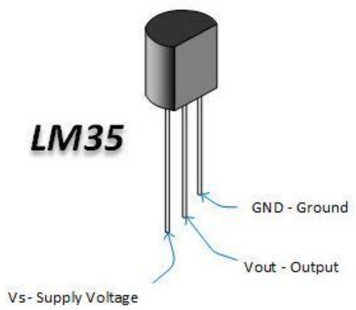

Figure 12: LM35 Pin Diagram

IV. SOFTWARE IMPLEMENTATION

A. Flow Chart of the Entire System

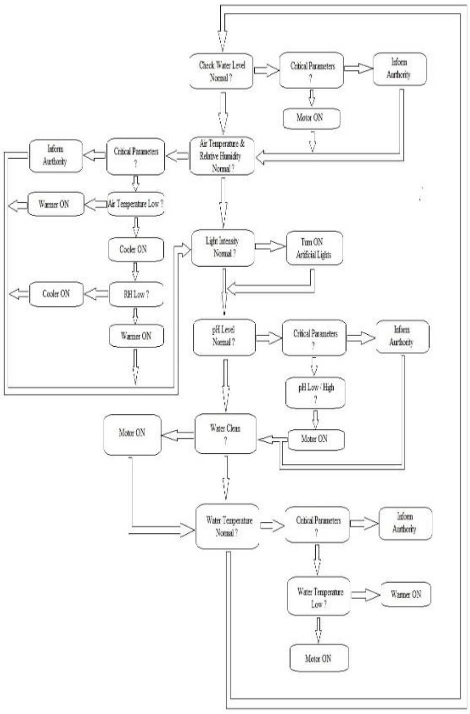

Figure 13: Flow Chart

V. WORKING MODEL

The completed working model of Real-Time Monitoring and Control of Solar-Powered Aquaponics System using LabVIEW is as shown in figure 14 below.

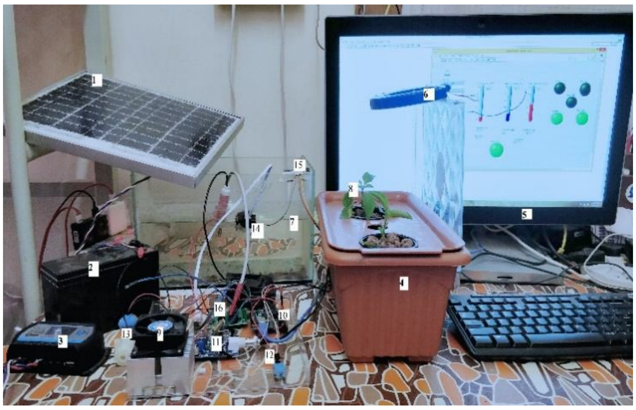

Figure 14: Working model of Aquaponics system

VI. RESULTS AND DISCUSSION

The below figure 15 shows the output results of the overall automated greenhouse aquaponics system which contains the control and monitoring parameters such as water level, air temperature, relative humidity of greenhouse, light intensity, pH , turbidity and water temperature of aquaponics system.

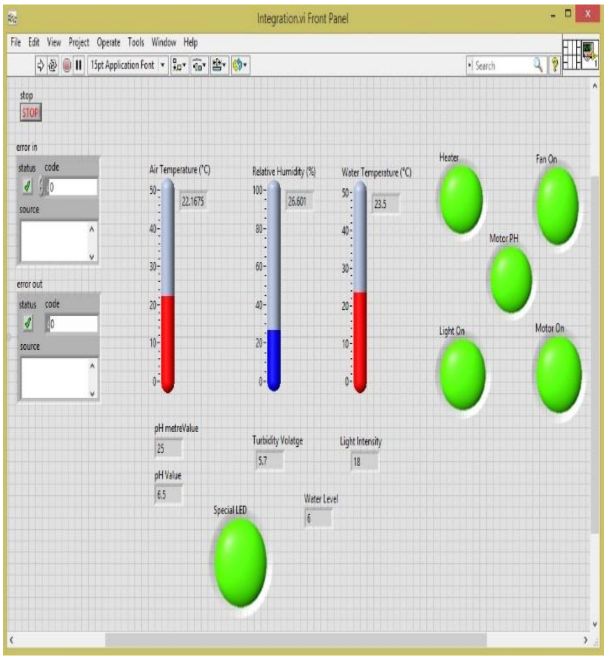

Figure. 15: Overall automated aquaponics system front panel

The environmental parameters read from the sensors and status of actuators are listed in the table I below. Before actual testing the sensors are calibrated for close required values.

Greenhouse Control and monitoring system								
Time	Environmental parameters		Status of actuators				Mail from PC	Outside temperature
	T_{air} (^{0}C)	RH (%)	G	F	E	W		
8:00	24	95	1	1	0	1	0	20
10:00	27	78	1	1	0	1	0	23
12:00	30	61	0	1	0	1	0	26
14:00	31	47	0	1	0	1	0	27
16:00	31	44	0	1	0	1	0	27
18:00	29	52	0	0	0	1	0	25
20:00	26	68	1	0	0	1	0	22
22:00	25	82	1	0	0	1	0	21
0:00	24	94	1	0	0	1	0	20

Table I: Data from greenhouse control and monitoring system taken in winter

Table I shows that air temperature increases during day and decreases during night. Due to cold weather in India warmer lamps are always on. Greenhouse light and exhaust fans are actuated for a while only. The greenhouse temperature is kept 40C above outside temperature for best growth of plants.

VII. CONCLUSION AND FUTURE WORK

The aquaponics system allows plants and fish to co-exist in an interdependent and controlled environment in almost all seasons. In the design and construction of hydroponic beds and aquaculture tank, waste product management and water recycling process are demonstrated.

An automated aquaponics monitoring and control system was done with low maintenance cost and minimal human intervention. The experimental results showed that the overall system's performance was sustainable for weather conditions in India. The project is demonstrated in NI LabVIEW program can be useful tool in reading and logging values of all parameters used in the system.

The solar power conversion set-up supplied electricity to the aquaponics and greenhouse system. However, to ensure that the system is powered-up reliably 24 hours a day and 7 days a week, solar panels and batteries with higher ratings are required and control optimization can be explored as future directives. Implementation of further sensors like CO2 sensor, DO sensor, TDS sensor, TAN sensors can be explored as future directives. The project has been implemented by gathering information about design of aquaponics system through social media, visiting to nearby farms. A business plan for implementing this project in a large scale is recommended to support a possible source of livelihood for the local communities.

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